Incident report: COUPP-60 burst hydraulic line, 7/19/2011, 6:00 PM

On Tuesday, July 19, we started filling the COUPP-60 inner vessel with CF3I at around 11 am. The fill procedure went smoothly during the day. At around 4:30, Andrew Sonnenschein and Hugh Lippincott went underground to finish the CF3I fill and get ready to warm the detector to room temperature. Figure 1 shows the pressure history during this period, with the x-axis running from 4 PM to 7 PM. At 4:45, we let the air out of the backside of the piston, resulting in the drop in the cyan points (the air pressure in the reservoir) and the drop in the blue circles from 80 to 0 (representing the drop in piston position from 8 inches down to 0). We then proceeded to pull out glycol until the bellows position reached 0.5 inches (not shown), lowering the pressure in the system (the drop in the red and light green points between -2.5 and -2 hours).

A little before 5:30 PM, we had completed the CF3I fill, closing the valve between the fluid handling cart and the inner vessel. At this point, we began pressurizing the glycol using the pump (the magenta and black exes represent 50 and 40 times the boolean value of the pump and EV47 respectively, so these are both ON during this stage). The slow increase in PT3 (the red squares) around -1.5 represents the final compression of all remaining CF3I gas into liquid before the pressure increases greatly due to the incompressibility of the liquid shortly thereafter. We then increased the air pressure on the back side of the piston (the cyan points increasing at -1.3) to move the piston up to about 4 inches (the blue circles).

Figure 2 shows a closeup of the same plot between 5:30 and 6:00 pm. At this stage, we were prepared to let water out of the inner vessel until the bellows reached the target position required before warming up the whole system. Andrew noticed that the piston was still moving upward even though we were no longer increasing the air pressure. On the plot, this can be seen as the blue points continue to move upward between -1.25 and -1.2 hours even though the cyan points are no longer increasing (as we stopped pressurizing the back of the piston). We lowered the pressure (the drop in the cyan points between -1.2 and -1.15) and decided to add glycol to the system to try to move the piston back down (the increase in the red squares and the dark green triangles at -1.15).

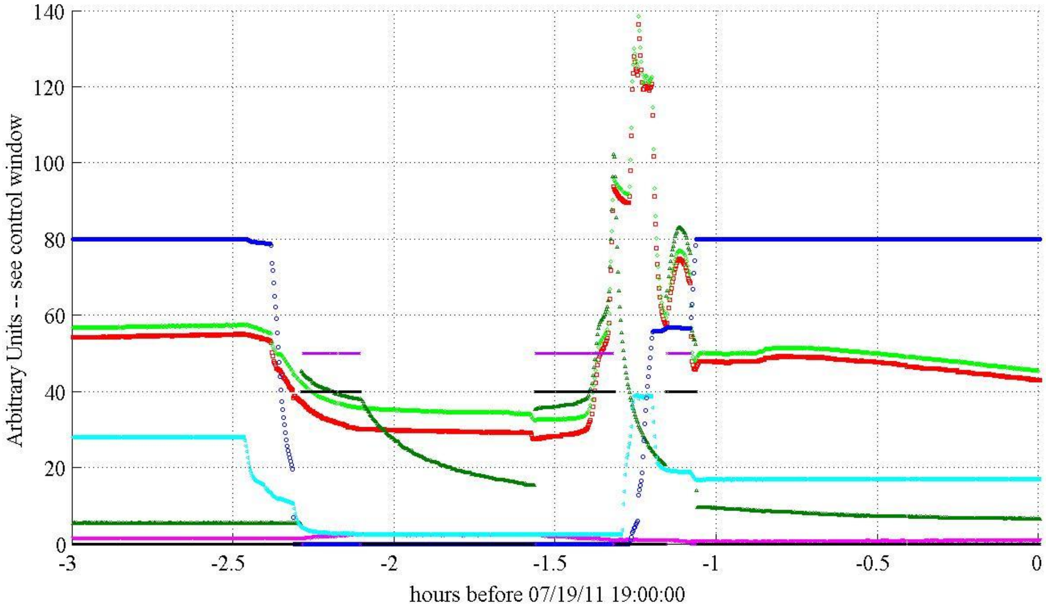


Figure 1 - LEGEND:
1) blue points - piston position x 10 (inches x 10)
2) green diamonds - PT83, pressure in the inner vessel (psig)
3) red squares - PT3, pressure of the glycol in pressure vessel (psig)
4) dark green carrots - PT41 pressure of the pump, downstream (psig)
5) magenta carrots - PT43, pressure of the pump, upstream (psig)
6) cyan carrots - PT7, pressure in the air reservoir (psig)
7) purple exes - Pump enable (0 or 50)
8) black exes - EV47, valve on the pump (0 or 40)

The jacket of the hydraulic line burst at about -1.075 and we immediately turned off the pump. It took another few minutes before we had closed all the other valves around the location of the burst line (MV 25, MV 27, MV 36), as well as MV 6 leading to the pressure vessel, occurring by about -1.06 hours in Fig. 2.

In all, about 1 liter of glycol could have escaped from the line. Most of the glycol went onto the floor - we diluted it with water and cleaned it up using black towel-like things which remain on the floor now. We also mopped up around the piston using the same black towel-like things. There was no flow of glycol and only an insignificant amount of it could have reached a drain.

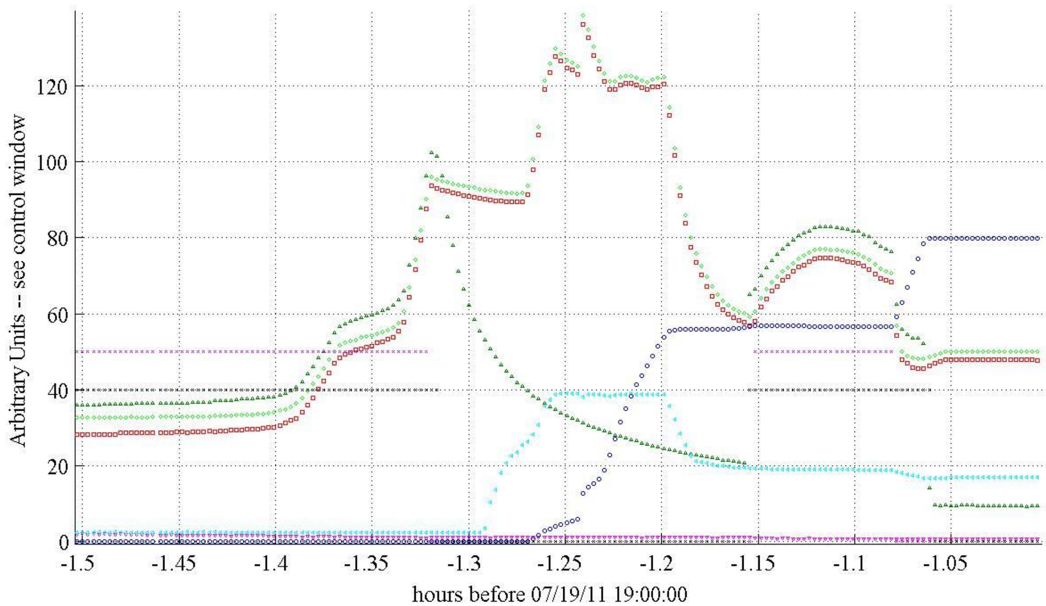
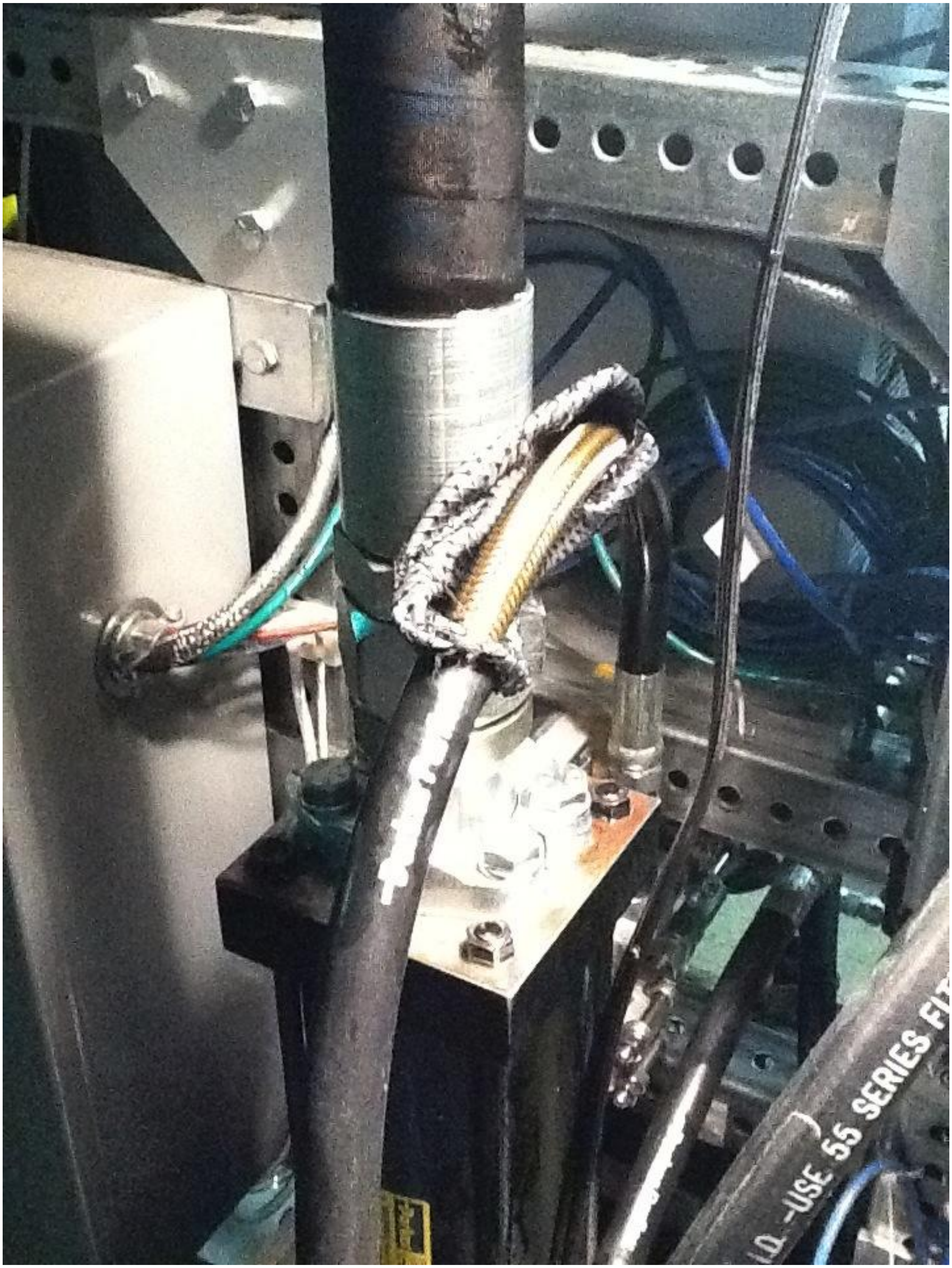


Figure 2 - LEGEND:
1) blue points - piston position x 10 (inches x 10)
2) green diamonds - PT83, pressure in the inner vessel (psig)
3) red squares - PT3, pressure of the glycol in pressure vessel (psig)
4) dark green carrots - PT41 pressure of the pump, downstream (psig)
5) magenta carrots - PT43, pressure of the pump, upstream (psig)
6) cyan carrots - PT7, pressure in the air reservoir (psig)
7) purple exes - Pump enable (0 or 50)
8) black exes - EV47, valve on the pump (0 or 40)

The highest pressure being recorded just before the burst was the pressure on the downstream side of the pump, at about 80 psig. We think that the most likely explanation is that a leak formed in the hydraulic line, and that we were forcing glycol into the jacket of the line, eventually bursting it. From the history, my best guess is that the leak formed just before -1.25 in the figure, when the pressure in the system was about 130 psig (the lines are rated for 2500 psi). Although the piston kept rising for the next few minutes, decreasing the total volume in the system, the pressure remained flat (with the exception of the small spike around -1.24 which can be attributed to a sticky piston getting unstuck). The pressure dropped when we backed off the air to the piston, while the piston did not - this is likely attributable to the sticky piston maintaining its position while glycol leaked out from the system. The leak then grew worse between -1.15 and -1.075 while we pumped glycol into the system until the line finally burst.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Next steps: We currently have the system isolated and the Neslab maintaining the temperature at about 5 degrees. As long as the power remains on, we can stay here indefinitely. If the power goes out or the Neslab fails, the liquids will warm up and expand, but with no volume into which to flow. Therefore the pressure will rise and eventually blow the relief valves (one operational at 300 psig, which is currently isolated, and two at 400 psig that can be switched between in case one blows).

While this is not the worst outcome, given that we would be able to switch relief valves, we would like to avoid it if possible. We have a temporary solution, which involves opening the system to the piston and pushing the piston all the way up at some relatively low back pressure. Therefore, if the temperature starts rising, eventually the pressure will force the piston down, providing about 1 liter of volume relief and providing us more time to get underground to address the problem. In this configuration, we would have MV 3, 7, 2, 5, 27, 31, 36 and 48 closed, but keep MV 6 open, allowing the system access to the piston.

While the system expands, in the time granted by the maneuver with the piston, we could then open the system to the degassing vessel to provide a volume for the glycol to enter. To do this, we would open MV-31, 48, 44, and 75, while keeping MV-50, MV-39 and MV-26 closed. We would probably want to throttle the flow, which could be done by carefully opening and closing MV-48 as the pressure increases. If the power is on and the neslab has broken down independently, this would safely recover the system. If the power is off, we would like to have some independent measure of the pressure in the system, which could be obtained with PI-1 by opening MV-7.

Replacing the hose: We are hoping to look at the hose to ascertain the cause of failure (potential sources include the crimp, a bad hose, or chemical incompatibility). If we identify the problem, we can attempt to rectify it, but even if none of these things can be identified as the cause of failure, we will eventually have to do something with the system. My current inclination would be to replace the hose, pressure test the external system at our operating compression pressure and then proceed with the run as originally planned. The biggest hazard is that a hose fails while operating the system and no one is underground. In this case, we would lose the ability to control the pressure and we could damage the bellows of the inner vessel, unless it manages to hold the vapor pressure of CF_3I (it is expected to survive up to 72.5 psi, and the vapor pressure of CF_3I at room temperature is about that level). We might also get a sign of a leak from the slow controls and have time to isolate the system, returning the situation to the current one.